The Learning Process and the Market: The Japanese Capital Goods Sector in the Early Twentieth Century

by

Tetsurō Nakaoka
Faculty of Management, Osaka University of Economics

Discussion Paper
No. JS/94/271
January 1994

The Suntory Centre
Suntory and Toyota International Centres for
Economics and Related Disciplines
London School of Economics and Political Science
Houghton Street, London, WC2A 2AE, UK.
Tel. 020-7955 6698

Preface

Professor Tesurō Nakaota, formerly of Osaka City University, and now of the Faculty of Managementm Osaka University of Economics, gave a seminar on Japanese industrial development at the Suntory-Toyota Centre during 1992. Although it was not possible to publish that paper as a STICERD discussion paper, we are extremely grateful to Professor Nakaota for allowing us to reproduce the present paper. STICERD would also like to express thanks to Dr K Sugihara of the School of Oriental and African Studies, University of London, for assistance with the English version of the paper.

Janet Hunter
January 1994

Keywords: Japan; capital goods sector; market; learning process; early twentieth century; Hong Kong; Taiwan; machine-tool industry; Alice Amsden; Martin Fransman.

The Learning Process and the Market: the Japanese Capital Goods Sector in the Early Twentieth Century

by

Tetsurō Nakaoka

This study is inspired by two pieces of research carried out around 1980: Alice Amsden's research on the Taiwanese machine-tool industry of the 1960s, and Martin Fransman's work on the learning process of the infant capital goods sector in Hong Kong. In the 1980s these two pieces of research strongly influenced each other, leading to Amsden's work on the Korean machinery sector and Fransman's comparative study of the Japanese and Taiwanese machine-tool industries. Fransman then made a further study of the learning process in the Japanese semi-conductor industry.[1] It remains the case, however, that Amsden's and Fransman's earliest works are a source of stimulation to Japanese historians of technology, because some aspects of the infant capital goods sectors in Taiwan and Hong Kong described show a strong similarity to those found in the small concerns which existed within Japan's metal and machinery sector early this century - the bottom half of the so-called 'dual structure' of the Japanese economy.

Japanese scholars have long regarded the existence of these small metal and machinery concerns as a sign of the backwardness of the Japanese economy, inhibiting the technological upgrading of Japanese industry. The study of the technical learning process in these small concerns has consequently been a somewhat neglected field of Japan's industrial history. However, the work of Amsden and Fransman strongly suggests that these small metal and machinery concerns may have been a representative part of the infant capital goods sector which will evolve spontaneously at a certain stage of late-comer industrialization. The object of this paper is therefore to compare the learning processes described in Amsden's and Fransman's works with the Japanese case, and to make a contribution towards our understanding of the formation of the capital goods sector in developing economies. For convenience of comparison the paper will focus on the machinery sector. Some general remarks will first be made concerning aspects of the Japanese machinery sector at the beginning of the twentieth century, showing the situation within which small concerns operated, and the similarities and differences compared with Taiwan and Hong Kong. The second part of the paper will be a more detailed examination of the technical learning process in Japanese concerns with special reference to the role of market conditions. Finally, some theoretical implications will be discussed.

Small Firms in the Japanese Machinery Sector in the Early Twentieth Century

The Japanese machinery sector was beginning to develop certain distinctive features by around the turn of the century. Table 1 shows the distribution of private firms in this sector in 1911. Relatively large enterprises are found in areas such as shipbuilding, rolling stock and electrical engineering, reflecting successful development in heavy industries. Not included in this table is the substantial government sector which also existed, consisting mainly of arsenals and factories related to the National Railways. A further characteristic of this sector was the very large number of small firms: 84% of firms shown in the table were small operations employing fewer than thirty workers. Since the official statistics summarised in Table 1 omit firms with fewer than five workers, we can assume that there were also a much larger number of small and household concerns. This contrasting structure - the existence of well developed large firms in a few specific areas of manufacturing at the same time as a mass of small or micro firms right across the sector - was characteristic of Japanese industry at the time. It is this that has been referred to as the dual structure of the economy. This structure has been the subject of considerable debate, and the extraordinarily large proportion accounted for by the government sector and the importance of arsenals has received particular attention.[2] It is sufficient here to make just one point, as background to the analysis which follows.

The arsenals certainly played an important role as a source of skilled mechanics. In the first half of the Meiji period, arsenals were the largest, and virtually the only engineering firms in Japan which had a surplus of skilled mechanics. It was those mechanics surplus to the needs of the arsenals who at an early stage introduced modern engineering into the private sector. As I have shown in a previous work, the development of the private sector during the Meiji period was largely dependent on the operation of the traditional sector.[3] The defects in old-fashioned, traditional techniques were frequently compensated for by the introduction through these arsenal mechanics of certain modern engineering techniques, and this contributed greatly to development. It is said, for example, that one mechanic who had left the Yokohama Naval Arsenal was responsible in the early Meiji period for introducing Western moulding techniques to the town of Kawaguchi, a traditional centre of the foundry trade, laying the basis for its subsequent development as a centre of the modern iron casting industry.[4]

It is also well known that local silk reelers in Nagano Prefecture developed a hybrid silk reeling technology, which enabled them to make a major contribution to the growth of the industry in the 1880s. The core of this technology was reeling equipment originally copied from the West, but extensively simplified and modified, combined with the use of steam for the processing of cocoons. While the reeling equipment itself was manufactured by local carpenters, the steam boilers were supplied mainly by three manufacturers: a local inventor who had started off as a traditional coppersmith and learned engineering knowhow from a government factory, and two mechanics who had formerly worked for arsenals.[5]

Encouraged by these pioneering examples, a considerable flow of mechanics from the arsenals and from a few large private engineering companies continued during the latter half of the Meiji period to supply various manufacturing sectors with access to modern engineering techniques. The existence of the numerous small firms shown in Table 1 (and those not shown, which were even smaller) may well have been the result of an interaction between this flow and the considerable development based in the traditional sector. Although it is impossible to provide statistical evidence, the descriptive sources we have, notably the biographies of entrepreneurs of the period, strongly suggest that this was the case.[6]

It is important to be able to identify the kind of markets in which these small machinery concerns were able to pursue their business opportunities. Fortunately it is possible to identify the main products of each factory from the official factory statistics (Kōjō Tsūran) produced by the Ministry of Agriculture and Commerce (Nōshomushō). Table 2 summarises the results of the 1911 list of factories, showing the products of all factories with fewer than thirty employees recorded under the heading of the machinery sector. Roughly speaking, there were three major areas of production: prime movers for small firms, such as kerosene and gas engines, steam engines and steam boilers; means of short distance transportation, such as small steam boats, fishing boats, carts and bicycles; and equipment and appliances for urban living, such as pumps for fire engines, metal products for buildings, and appliances for electricity, gas and water supply. The presence of local inventions is also conspicuous: narrow-width power locms, rickshaws, noodle manufacturing machines and rice milling equipment were all locally developed. As we shall see later on in the case of narrow-width power looms, products such as these provided local small firms with good business opportunities, because there was no foreign competition.

On the whole, Table 2 gives an accurate picture of the contemporary situation of Japan's industrialisation. Although large companies were growing rapidly in industries such as cotton spinning, silk reeling, mining, shipbuilding, railways, gas and electricity supply, the economy as a whole still depended heavily on small and household concerns, both in export-oriented local industries, and in the traditional sectors of agriculture, forestry and fishery. However, mechanisation was beginning to diffuse into these small concerns, and their demand was growing for small prime movers, simple machinery and cheap vehicles for transportation. On the other hand, lifestyle changes in large cities like Tokyo and Osaka created demand for new types of machines and appliances, for instance those required for the distribution of electricity and gas to individual homes.

Part of this new demand was met by large companies. It was large companies which produced, for example, transformers and electric motors. However both the ordinary members of the population and small entrepreneurs in this period were relatively poor, meaning that demand was decisively oriented towards cheap goods. In general the products of large companies were beyond the reach of these people, with the consequence that small concerns at the bottom of the dual structure were provided with business opportunities. The dual structure of suppliers was thus conditioned by a dual structure of demand. For example, the demand for prime movers came not only from small firms, but also from large companies, but the latter demand was largely for high-quality products, and was met by imports, or by large shipbuilders or equivalent firms. The demand from small firms, however, was exclusively for cheaper products, and was met by small firms. Table 2 can therefore be regarded as showing the pattern of demand at the bottom of the dual structure of the market. It can be seen that the table includes eighteen small machine-tool builders. These producers naturally responded to the demand for cheap and simple products coming from the small concerns appearing in Table 1.

Similarities and Differences in the Cases of Japan, Taiwan and Hong Kong

In the above-mentioned article, Alice Amsden states that:

> 'The earliest users of Taiwan-made machine tools were small, family-operated concerns in the metal and machinery sectors. They

> were engaged primarily in processing and repairing and secondarily in manufacturing. In 1961 such concerns numbered 2,000. Machine tools would be indispensable to such concerns for the repair of products like bicycles and taxis; rice milling equipment and agricultural implements; as well as for the manufacture of spare parts for these products.
>
> The purchase of machine tools by small machine-making and metal working enterprises was also important. Such enterprises would require machine tools for maintenance purposes, as well as for the production of hand tools and cutlery, nails and chains, bicycles and miscellaneous machinery. An unincorporated concern with 45 workers, engaged in the production of semi-automatic shoemaking machinery, appears typical. It purchased all its machine tools locally.'[7]

This picture is remarkably similar to the world shown in Table 2. Products such as bicycles, rice milling equipment and agricultural implements were present in both cases. We must of course be aware that the historical context of Japan in the 1920s was quite different from that of Taiwan in the 1960s, but it is perhaps still possible to summarise the similarities between the two cases along the following lines. Firstly, in the early stages of industrialisation new demand was created for machines on the periphery of development - small prime movers, boilers, pumps, rice milling machines and power-driven agricultural implements - and for their maintenance and repair. Secondly, leading companies were not interested in meeting such demand, because the pressure for low-priced goods was too great. The result was that opportunities were provided for the growth of numerous small manufacturing firms and family-operated businesses. Thirdly, these small concerns in turn created new demand for the capital goods which they themselves needed. This demand was again not met by leading companies, encouraging the growth of small capital goods manufacturers.

Martin Fransman, meanwhile, describes a slightly different picture of the growth of the capital goods sector in Hong Kong. Here it was export-oriented labour-intensive industries, that is, the leading industries, that provided small capital goods manufacturers with their business opportunities. In most cases a worker in a firm which either produced machinery or was involved in metal processing would leave that firm after acquiring a minimal level of saving, and start his own firm. "In the early stages the new firm was involved in relatively simple operations: maintenance and repairs of machinery, the production of spare parts and related subcontracting operations."[8] This description can easily be applied to the birth of small engineering firms in Meiji Japan. As we shall see later, the development of Ikegai Tekkō (Ironworks), prewar Japan's top machine tool manufacturer, was very much according to this pattern, and the same may also be true of Taiwan. However, the second step of development in the two countries was very different. In Hong Kong local manufacturers in the export-oriented industries began to request their producers either to copy imported machines or to make a new machine designed to serve specific purposes. "The user was usually motivated by one or more of three factors in making its requests: (a) the possibility of replacing the imported machine with a locally produced model with a lower cost; (b) the possibility of obtaining a machine of more appropriate design; and (c) deriving the benefits of cheap and quick maintenance and repair services."[9]

One problem with export-oriented labour-intensive industries is the high capital cost of imported equipment. Another serious problem is the gap existing between sophisticated imported equipment and the low operational skills of local workers. In addition, industry in Hong Kong suffered from the conflicting pressures of rapid growth and the very small size of the territory. Space-saving devices were vital to manufacturers' operation. These various factors created a demand for imported machinery to be modified by local manufacturers, and it was this demand which encouraged the rise of local capital goods manufacturers.

The first step in the case of Hong Kong was thus very similar to what we find in Japan and Taiwan, while the second step was very different. There may therefore be a variety of situations which can encourage the rise of a local capital goods sector. We need to ask whether there is any principle or dynamic model of the learning process which can explain comprehensively these similarities and differences, and, as a consequence, enable us to predict the possible courses of development of the capital goods sector in late industrialising countries. To answer this question more case studies like those of Amsden and Fransman need to be compiled. In this paper two Japanese cases are examined: narrow-width loom manufacturers and machine tool builders. The former provides an example specific to Japan, while the latter example is more comparable with the cases of Taiwan and Hong Kong.

The Case of the Narrow-Width Loom Manufacturers

Table 3 gives the sectoral distribution of the textile machinery firms shown in Table 1. The majority of firms are in the weaving or cotton spinning sectors. It is only in these two sectors that we find relatively developed manufacturers (according to the tentative criterion of having over fifty workers). However, the nature of these more developed firms in the weaving and spinning sectors was very different. Japan's modern cotton spinning sector grew rapidly from the late 1880s using imported equipment. As it grew, so, too, did small firms, exploiting business opportunities offered by repair work or the manufacture of simple parts of equipment. Around the turn of the century some of these firms began to manufacture simple machinery, such as tamashimeki (the bunding press). The development of the spinning sector was so rapid that the production of several such primitive machines was sufficient to sustain the growth of these small firms. Around the time when the data given in Tables 1 and 3 were collected, these firms were already beginning to copy some of the key machines in the spinning process.

By contrast, developed firms in the weaving sector were all manufacturers of narrow-width power looms, a locally-developed technology. The early development of the weaving sector was based exclusively on traditional technologies and modes of production. One important reason for this was the use of the kimono, the traditional Japanese form of daily clothing. Kimono cloths were narrow in width (roughly 28cm.), and Western broad-width looms could not be used for the weaving of kimono cloth. However, Western influences did cause innovations in the traditional weaving technology. For example, the adoption of strong imported cotton yarn for use as the warp thread permitted the application to cotton weaving of the silk loom, which was more efficient than the traditional cotton loom. This significantly increased the productivity of cotton weaving. Another innovation was the introduction of the flying shuttle, which, it is estimated, doubled the productivity of the weaving sector. In this way the traditional weaving industry was able to develop through indigenous innovations stimulated by Western influences.[10]

As a consequence, traditional loom carpenters, that is, traditional capital goods manufacturers, were able to expand. Those local inventors who were able to acquire carpentry skills and related knowledge from the study of imported Western machines found in this sector the best opportunities. The traditional narrow-width, wooden treadle loom was first modified by the use of the flying shuttle, then became a foot loom, in which shedding (kaikō) picking (tōhi) and beating (osauchi) were carried out automatically by the use of foot pedals, and finally developed into the narrow-width power loom. The engineering skills required for the construction of the narrow-width power loom were hybrid in nature. The main frame was wooden, so in this respect construction techniques were based on the traditional carpenter's skills. However, inventors also engaged in intensive study of imported looms and textile machinery, and introduced many Western techniques. Modern engineering techniques and the use of iron parts were particularly necessary where prime movers and power transmission systems were concerned. There was therefore a mix of indigenous loom carpenters' knowhow and primitive engineering techniques drawn from the infant modern sector. Such hybrid engineering could not, of course, produce machinery suitable for the modern sector.[11]

The narrow-width power loom was welcomed by weavers specialising in the manufacture of white cloth, namely those in Enshu (Shizuoka), Chita (Aichi) and Sennan (Osaka) for cotton weaving, and in Fukui, Ishikawa and Daishoji (Ishikawa) for silk weaving. The traditional treadle loom equipped with a flying shuttle was still appropriate for the weaving of ikat and stripes, but the narrow-width power loom proved extremely efficient for the weaving of white cotton and silk. Along with the diffusion of power looms, large weavers in these regions began to adopt the factory system. Productivity in these factories rose enormously. Many of the old family-operated concerns disappeared, and former family workers began to work in the factories. The traditional sector in these regions was thus metamorphosed into the modern sector, truly a remarkable innovation.[12]

This process went on between about 1900 and 1920. Most of the narrow-width power looms which enabled this change were produced by small firms. Ishii Tadashi, a historian of loom manufacture, estimated that nearly half of these looms were produced by micro firms with fewer than five employees, which were omitted from the official statistics.[13] All the firms in the upper part of the column entitled loom builders shown in Table 3 would have been successful manufacturers, who had made considerable profits and enlarged the size of their factories. In other words, they had accumulated both the capital and technical capability needed for the next step of development.

Around this time these white cloth producing regions were beginning to engage in exports. This required the production of broad-width cloth, and hence the use of broad-width looms. Moreover, modern cotton spinning firms began to operate their own weaving mills, creating a demand for locally manufactured looms of Western standard width. Both of these factors changed the nature of demand for broad-width looms. However, this presented loom manufacturers with a considerable technical problem. In a narrow-width power loom the mechanical shock of beating was relatively small, and could be withstood by wooden construction. By contrast, the shock of beating in a broad-width power loom was far too great for a wooden frame to cope with, necessitating the use of an iron frame. The fine nature of the iron frame required meant a higher level of casting techniques. Moreover the mass production of larger scale iron constructions in itself necessitated considerable technical upgrading in areas such as the precision of machining and assembling, the standardisation of products and processes, and the improvement of guages and tooling in metal processing. In short, what was needed was a 'technical quantum leap' from the earlier hybrid engineering to Western standard mechanical engineering.

One typical example of a manufacturer who made this leap successfully is the Toyoda Loom Works. Toyoda was perhaps the largest loom manufacturer shown in Table 3, employing 196 workers and probably possessing the highest technical competence of all indigenous loom manufacturers at that time. Despite this, even Toyoda was not able to make the required leap without outside help. The firm invited Charles Francis, at the time a professor of mechanical engineering at Tokyo Technical College, as a technical adviser. Toyoda is said to have been very keen to follow Francis' advice; in accordance with his instructions, it invested considerably in its foundry, imported many high precision machine tools, prepared various gauges and toolings, and promoted standardisation.[14] This process was enabled by the relatively large accumulation of capital by Toyoda. Table 4 shows clearly how Toyoda about 1908-9 made this quantum leap and developed the broad-width power loom. Some other manufacturers followed Toyoda's example, while the remainder were left with the stagnating demand for narrow-width looms.

The new level of engineering capability reached through this quantum leap enabled Toyoda to cultivate a new field of business. The company absorbed the Kimoto Iron Works, at the time Japan's leading company in the manufacture of cotton spinning machinery, and started to build up its capacity for the manufacture of spinning frames. For the first time in Japan, in 1920, it succeeded in constructing a full line of spinning factory equipment.[15] At the same time, Toyoda Sakichi, who had been trained as a carpenter and was the original founder of the Toyoda Loom Works, managed to perfect his invention of the automatic shuttle exchange system based on his experience of developing the broad-width power loom. It should also be noted here that a change in entrepreneurship was necessary for this quantum leap to be achieved. Sakichi's enthusiasm for invention had been an integral part of his leadership during the company's manufacturing of the narrow-width loom. However, at the new level reached following the leap, a new type of management was required. Sakichi could not comprehend the need for change, and was eventually forced to leave the company. He established a new company to perfect his invention, and was successful in doing so with the help of his son, Toyoda Kiichirō, a young graduate from the Department of Mechanical Engineering at Tokyo Imperial University. It was Kiichirō who actually perfected the invention of the automatic shuttle exchange system, and who took the lead in the construction of a mass production line for automatic looms in the 1920s. This served as a good preparatory training both for Kiichirō himself and for the new company, Toyoda Automatic Loom Works, helping them to make a later quantum leap to the manufacture of automobiles (i.e. the change to Toyota Motor Corporation).

Although Toyoda's case was conspicuously successful, it was not unique.

Suzuki Loom Works made a very similar series of leaps from the manufacture of narrow-width looms to the manufacture of small cars and motor cycles (Suzuki Motors). The manufacture of narrow-width looms thus played an important role as one of the springboards for the technical quantum leap in the history of the Japanese engineering industries.

Toyoda's Experience in Comparison with Taiwan and Hong Kong

Can we draw any lessons from Toyoda's experience for the infant capital goods sectors of developing countries today? Unfortunately, the accelerated growth of the traditional sector in Meiji Japan was strongly conditioned by the historical situation of the time, and the experience cannot be reproduced in contemporary developing economies. Nevertheless, it may be helpful here to note some common aspects of the above process and the cases of Hong Kong and Taiwan. The case of narrow-width loom manufacturers can also be viewed as an example of a more general tendency, whereby a situation favourable to the growth of small indigenous capital goods manufacturers can be created at a certain stage of industrialisation. What then are the factors which may condition such a favourable situation?

One important factor may be the local specificity of requirement. In Japan this requirement was conditioned by the prevalence of traditional clothing, the kimono. Likewise in Hong Kong manufacturers required space-saving innovations, as this demand was conditioned by the geographic circumstances of Hong Kong. Such a requirement is specific to a particular locality, and will not be common to all countries, so local engineering may be the most appropriate to respond to such a demand.

Any country will have its own specific requirements according to its own social, geographical, cultural and historical conditions, and some of these may be favourable to the growth of small, local firms.

It may, however, be more important to note local requirements common to all three countries. For instance, both in Taiwan and Hong Kong repair and maintenance work played an important role in the business of small firms in the early stages. Such work, by its very nature, requires local engineering resources, and can perform an important role in any country in the initial training of small capital goods manufacturers. Demand from the primary sector is also crucial. Neither peasants nor fishermen are skilled in the operation of machinery. The capital goods which they use are therefore in frequent need of technical servicing. Such a circumstance is highly favourable to local manufacturers. This becomes clear in the case of Japanese machine tool and engine manufacturers, as we shall see later. Another crucial factor is the requirement for low-priced goods. Alice Amsden's work confirmed that this requirement was dominant in the Taiwanese machine tool market in the 1960s. It was certainly a decisive factor in the Japanese loom market in the Meiji period as well. Ishii Tadashi's work has confirmed that the narrow-width looms which were mainly used by weavers were all priced at Y20-30, while imported power looms were priced at around Y300-400.[16] It should be stressed that this is not the same as the problem of technical choice between labour-intensive and capital-intensive technologies. Imported looms were completely beyond the reach of local weavers. The only question which mattered was whether or not local manufacturers could provide them with extremely cheap looms. In this respect the very low labour costs typical of latecomers to development must always be favourable to the growth of local manufacturers. This may also have been the case with the Taiwanese machine tool market of the 1960s. It was certainly the case with small Japanese manufacturers in the 1920s.

Thus a combination of local specificity of requirement, a low level of mechanical skills of the user, necessitating frequent technical servicing, and an overriding need for cheap products, is likely to ensure the rise of a local capital goods sector, or, to be more precise, local engineering services. At this stage the low technical skills available locally are not likely to be a serious problem. It is important to note that the low skills of capital goods suppliers are often well-matched to the low technical level of users. Japanese loom manufacturers were only able to produce narrow-width looms of mixed iron-wood construction. However, all users wanted were simple and cheaply constructed narrow-width power looms. In Hong Kong the skills possessed by machine builders were not good enough to design a new and original model; they were better adapted to copying, modifying and simplifying a given model. However, this was exactly what their customers in the export-oriented manufacturing sector wanted. Likewise Taiwanese machine tool builders could only produce simple lathes, bench drills and low quality punch presses.[17] However, what small engineering firms required, not only in Taiwan but also in other Southeast Asian countries, was exactly this kind of simple, cheap machine tool. The primitive capital goods they supplied were therefore welcomed by the users. Their diffusion into the industry was rapid, and their effect innovative. The influential view that the capital goods sector in a less developed country cannot generate innovation due to its low technical capability ignores the effect of this kind of matching.

One can, in fact, find many innovations in the histories of both Japan and other developing countries which result from this matching. The matching encouraged the development of related industries, and thus enlarged the market for capital goods, providing manufacturers with an opportunity for capital accumulation. However, it is also extremely important to note that this kind of development will eventually take away the whole basis upon which the matching takes place. For example, once the development of the Japanese weaving sector resulting from indigenous innovations was linked to the export market, demand began to shift towards broad-width looms. The result was that the matching between Japanese suppliers' technical capability and customer demand ceased to exist. Similarly, when the export market for Taiwanese machine tools shifted from Southeast Asia to Japan and the USA as a result of the development of the industry, user demand ceased to be compatible with the technical capability of suppliers.[18] Manufacturers were thus faced with the need for a technical quantum leap. This, perhaps, is the reason why, if the economic growth of developing countries is to be sustained, constant efforts at technical upgrading are needed. Development creates a mismatch between technical capability and market demand. The match between the two is recovered by means of a technical quantum leap, and development resumes, producing in its turn another mismatch. The technical learning process here appears as a series of quantum leaps, and not as a continuous, gradual process of progression. The Japanese experience shows this particularly clearly.

The above discussion suggests that we should not concentrate only on the in-house learning process. We need to pay equally close attention to the relationship between market conditions and the technical capability of suppliers, and the resulting need for a technical leap. Bearing this point in mind, we will now examine the circumstances of the Japanese machine tool industry in the 1920s.

The Machine Tool Market in Japan in the 1920s

Sawai Minoru's research has shown that in the 1920s the Japanese machine tool market possessed a hierarchical structure. A diagrammatic representation of this structure is given in Figure 1.[19] The market as a whole was divided into four sections; these could be arranged hierarchically according to technical level and price range. The higher up the hierarchy the market, the more sophisticated, more accurate and expensive the product. Each sub-market had its specific customers, and to some degree functioned as a separate market from the other sub-markets. Each sub-market also had its own specific suppliers, who had reached the level of technical capability required to produce for that sub-market.

This structure has considerable implications for our present study, because it can provide an insight into the interrelationship between the market and the technical learning process in a developing country. The upper part of the structure may well be influenced by demand from leading industries largely dependent on imported technology and equipment. The lower part represents demand from small firms, evolving mainly on the basis of indigenous engineering capacity. This structure may therefore be common to the capital goods market of other developing countries. If we use Alice Amsden's conclusions to draw up a comparable figure for the Taiwanese machine tool market in the 1960s, we obtain

Figure 2. As can be seen, the figures are broadly similar, the only difference being that in Taiwan private manufacturers supplied only the bottom sub-markets, while in Japan there were also manufacturers supplying the top sub-markets, suggesting the presence of technical upgrading.

The markets in the lower half of the hierarchy, and their suppliers, are in both cases strikingly similar. In 1929 the official Japanese factory statistics (<u>Kōjō Tōkeihyō</u>) for the first time listed machine tool manufacturers as a separate category, showing a total of 465 manufacturers and an impressive concentration of small firms (Table 5). This preponderance of small firms remained unchanged in 1936, when the total number rose to 771. Likewise, in the Taiwanese case, Amsden reported that "in 1966, 80% of all machine tool firms had fewer than twenty workers. While the situation had changed somewhat by 1973, less than half of all machine tool builders employed more than twenty workers, and only a handful employed more than a hundred."[20] If we substitute the years 1929 and 1936 for the years given by Amsden, the words can be applied to Table 5 without modification.

In Japan the quality of products in this market was not only poor, they also deteriorated very fast. One survey report on the machine tool industry commented, "Most radial drilling machines and milling machines made in Japan have to be discarded after one or two years' use - in the worst case, after a few months."[21] The reasons for this were factors such as inadequate choice of materials, low quality of castings and the low technical level of heat treatment, very similar to those highlighted by Amsden in her study of Taiwanese machine tools in the 1960s. Amsden also complained of a lack of standardisation in Taiwan comparable to that of Japan in the 1920s. For small firms the main source of technology was the copying of imported foreign machines, or of the products made by suppliers to the upper market-groups. Manufacturers copied almost any machine regardless of region of origin or design standard. As a result, various standards coexisted within the products for markets in the lower half of the hierarchy. To take the example of screw threads, the American, French, Whitworth and various other threads were all in use, and there was no interchangeability between the various products.[22] As late as 1942, one Swiss engineer who came to Japan to give guidance on machine tool building complained that Japanese manufacturers failed to understand how in-house standardisation of the centre height of lathes was essential in designing jigs and fixtures.[23]

Perhaps the most important aspect which exists in common is the cheapness of products in the lower-level markets. In fact, there existed a big price differential for the same sort of product between the upper and lower sub-markets. According to Sawai:

> 'In 1930 the Kawasaki shipyard planned to invest in a set of machine tools. It was estimated that these would cost Y50-60,000 if they were purchased from top class suppliers such as Ikegai and Ōkuma, Y70-80,000 if the tools were to be imported, and Y20-30,000 if they were acquired in the second-hand market. Around the same time the price of six-foot lathes made by medium-sized and large firms ranged from Y380 to Y1,410. The price in the second-hand market was Y140-150.'[24]

We may assume that small builders' products were on average sold at a slightly higher price than second-hand products, although some would have been sold directly into the second-hand market.

It is reasonable to regard this lower level market, and its suppliers, as characteristic of the infant capital goods sector in developing countries. Alice Amsden has observed, however, that the very nature of this market inhibits the technical upgrading of its suppliers. The same observation has been made by Chudnovsky and others in their book, Capital Goods Production in the Third World. These authors stressed the following three points: first, that customers' strong demand for cheap goods encourages manufacturers to reduce prices at the cost of lowering product quality; secondly, that there is a possibility that others may quickly imitate the product, discouraging innovative activity; and thirdly, that, because of the low volume and instability of demand for the products of each firm, there is little incentive to achieve interchangeability of parts and standardisation of operation.[25] All these points were also emphasized by prewar Japanese research on small firms, resulting in their being regarded as a hindrance to technical progress in Japanese industry. Nevertheless, Figure 1 does clearly show that there existed five relatively large manufacturers who supplied the upper sub-markets, suggesting a higher level of technical capability. How, then, did they manage to escape from this trap, and achieve an upgrading process?

The Learning Process in the Five Big Manufacturers

The major machine tool manufacturers in the interwar period were Ikegai Ironworks, Niigata Ironworks, Ōkuma Ironworks, Karatsu Ironworks and Tokyo Gas-Electric (Gasu-denki) Industries, collectively referred to as 'the five big makers'. These machine tool builders were technological leaders in the industry, and built up the foundations upon which later development could take place. Their origins lay very much in areas of business other than machine tools, as indicated in Table 2. Three of them were listed in the 1911 Survey of Factories, but not as specialist machine tool makers. Ōkuma Ironworks was listed as a manufacturer of noodle-manufacturing machines, Niigata as a producer of oil engines, oil well drilling machinery and oil refinery equipment, and Ikegai as mainly a producer of oil engines and lathes. Karatsu and Tokyo Gasu-denki do not appear on the list. Tokyo Gasu-denki was growing as a manufacturer of gas supply equipment around this time. Given that the company's name includes the word for 'electricity' (denki) as well as gas, it may be suggested that originally it also intended to manufacture electrical equipment. However, its activities did not develop in that direction; instead, it embarked on the manufacture of arms, trucks and then machine-tools. The Karatsu case may well have been an exceptional one, as its development appears to have been based mainly on machine-tools. This was perhaps because it was started by Takeo Toshisuke, who had been trained in the United States as a machine-tool engineer, and for that reason received a considerable amount of help from the arsenals and other government factories. It remains true, however, that at least four out of the five big manufacturers were not originally specialist machine-tool builders, but started their operations in other related fields. Only after building up a certain level of engineering capability did they enter into the commercial production of machine-tools. I shall below take the example of Ikegai, the oldest of the five, and examine the learning process in some detail.

Ikegai Ironworks was established in 1889 by Ikegai Shōtarō. Ikegai had been a skilled mechanic at the Tanaka Hisashige Factory (later Toshiba), which was the largest private engineering firm at the time and an important reservoir of skilled mechanics. Ikegai's workshop was equipped with two 9-foot lathes he had manufactured himself, together with two second-hand lathes made in Britain. The fact that he was already able to manufacture his own lathes suggests that he had acquired a very high level of skill at the Tanaka Hisashige Factory.[26] Ikegai started off on subcontracting work from the Tanaka Hisashige Factory, at the same time manufacturing various machinery parts, including valves for the Tokyo City water supply system. He then progressed to the manufacture of machinery such as steam engines, cotton textile processing rolls (tsuyadashi rōru) and oil-fired engines, items typically shown in Table 2. The Sino-Japanese War of 1894-5 provided Ikegai with its first chance of making a leap forward. The fighting brought the company an order for small arms, enabling it to enlarge the scale of its operations. The number of workers increased from five to ten, and two new lathes were imported from Britain.

Although this was indeed a modest expansion, it led to a remarkable change in Ikegai's business activities. It began to develop new products in the fields listed in Table 2, the first being a cotton textile processing roller powered by a kerosene engine. While we may hesitate in calling this an innovation, there is no doubt that users actually welcomed the powered processing roller. From there, Ikegai developed a series of new products: such things as gas engines to serve as prime movers for small firms, hot bulb marine engines for fishing boats and cigarette manufacturing equipment. These products were welcomed in the market and enhanced Ikegai's reputation. The company grew rapidly, its recorded number of workers increasing from about sixty in 1905 to 205 in 1911.

The growth of the company paralleled the increase in its engineering capability. In the initial stages the greatest technological problem had been how to secure the prime mover of machinery. At first manpower had been used, an apprentice rotating a large fly wheel which drove the machine on the shop floor. This had greatly constrained the efficiency of operations, and when Ikegai enlarged the shop during the Sino-Japanese War he manufactured a small steam engine and installed it as the prime mover. Later, when Ikegai acquired the requisite manufacturing capability, this was replaced by a small gas engine.

The second important problem was perhaps gear cutting. At that time the use of a milling machine to cut gears was not customary practice among Japanese machine builders, except in the arsenals. The normal use of cast gears caused considerable noise and vibrations in the operation of the machinery, resulting in a low degree of precision and short product life. In 1897 Ikegai imported the latest US-developed universal milling machine, and began the machine-cutting of gears. Subsequently the company also imported an automatic universal gear cutter, and undertook gear cutting work subcontracted out by the naval arsenals. This advance secured a remarkable improvement in the performance of Ikegai's products.

Ikegai's progressive attitude towards technical improvement attracted the attention of some of the leading figures in engineering education. In 1899 the Naval Engineering Academy placed an order with Ikegai for five six-foot lathes and other machine tools. In 1905 Tokyo Technical College ordered two six-foot lathes. Through these orders the users hoped to provide Ikegai with a chance to challenge higher technical targets and further upgrade its technical level. The second of the two orders was especially important, because it was the Tokyo Technical College which sent to Ikegai the engineer Charles Francis, to provide guidance in engineering operations. As we saw above, Francis had also had connections with Toyoda.

Francis advised Ikegai on two occasions. In relation to the 1905 order mentioned above, he trained workers in the basic techniques of machine tool manufacture, for example the use of indicators and gauges, the cutting of high precision gears and screws, and the adjustment of the main spindle. He returned to Ikegai in 1906, and this time served as technical adviser for a year and a half. This time he introduced to the company batch production of standard models. He taught engineers about such things as the design of jigs and fixtures, and the layout of equipment on the production line, as well as advising management on what he considered indispensable machine tools for a first class machine tool manufacturer. These included among others special purpose tools for lead screw cutting, spindle drilling and gear cutting; machines for the manufacture of tools and small screws; and furnaces and equipment for heat treatment. In the same year, 1906, Ikegai Shōtarō joined in a partnership with Chiba Matsubei, formerly a cigarette manufacturer. Following Francis' advice, Ikegai is said to have invested most of the newly acquired capital from this partnership in importing new machine tools and equipment. This intensive activity aimed at technical upgrading may be regarded as comparable with the technical quantum leap made by Toyoda to produce the broad-width power loom.

Market Size and Alternative Courses of Technical Upgrading

The history of Ikegai gives us a rough understanding of the extent to which investment in equipment and engineering knowhow was needed for entry into the second sub-market, i.e. the market where there was competition between domestically-produced and foreign machinery. A large number of producer machines* were essential for entry into this market. The performance of manufactured machine tools was critically dependent upon these machines, which had in turn to be imported from the US. This meant that a relatively large amount of capital was needed, something which was generally beyond the reach of small manufacturers in the lowest level market. This was why Ikegai needed to accumulate capital as well as engineering expertise through the production of several innovative products (as with Toyoda's production of narrow-width power looms) before embarking on the batch production of machine tools. The noodle manufacturing machine played the same role in the case of Okuma. The case of Niigata was slightly different. Niigata started off as the machine shop of a relatively large oil company (Nippon Oil), manufacturing machinery for the boring of oil wells and refining of oil. Surplus capacity in the machine shop enabled Niigata to start manufacturing oil-fired engines, and then machine tools. These firms' experiences suggest that there were several alternative courses which could be followed to overcome the barrier of capital constraints and bring

---

* The word <u>mazaa mashin</u> (mother machine) is widely used by Japanese scholars to designate a machine tool used for the manufacture of machine tools. This has been translated here as producer machine.

about technical upgrading. As we shall see later on, Taiwan followed yet another course.

It was, however, very difficult for any of the small firms specialising in machine tools to follow any of these courses. The 1911 Factory Survey (Meiji 44-nen Kōjō Tsūran) lists eight specialist machine tool manufacturers, all of them small, with the largest employing only eleven workers. Only one of these, Wakayama Ironworks, managed to upgrade itself into a supplier for the second-level sub-market. This firm also developed into a general engineering company, with machine tools one of its main products. Entry into the lower-level sub-market as shown in Figure 1 was sufficiently easy for many manufacturers to engage in fierce competition within this relatively small market. As demand was exclusively oriented towards cheap products, price was a decisive factor in this competition. As long as firms manufactured cheap products at the expense of quality, they were able to maintain a level of production at which they could subsist. However, buying a high quality producer machine or investing in such things as casting technology were completely out of the question, so in order to overcome the barriers to the second level sub-market Japanese manufacturers had to find adequate sources of accumulation outside the machine tool market.

In Taiwan the situation appears to have been somewhat different. While Alice Amsden has confirmed the existence of similar barriers to the technical upgrading of small machine tool firms in Taiwan, the Taiwanese machine tool industry did begin to develop vigorously in the late 1970s. Exports played an important role in this development.[27] Even during the 1960s Taiwanese machine tools had been widely exported to Southeast

Asia, and this process had been accelerated by the Vietnam War. An enlarged machine tool market enouraged the entry of textile machinery manufacturers, such as Yang Ironworks, Chinkang Ironworks and Yungchin Machinery, all of which became leading manufacturers in later developments. These companies had acquired a relatively high level of engineering capability through their association with the development of the textile industry during the 1950s. During the stagnation of the textile industry after the 1973 Oil Crisis the focus of their production shifted from textile machinery to machine tools. Perhaps because of the enlarged export market, these companies did not need to combine production of several major products, something which had been essential for the Japanese manufacturers. By contrast exports had played only a limited role in the case of Japan. During World War I some machine tools were exported to Britain and Russia. In the 1920s some were sent to Northeast China, and in the early 1930s to Soviet Russia, but these are the only conspicuous examples. Japanese manufacturers had to face the problem of technical upgrading within the confines of a far smaller market than did the Taiwanese manufacturers, who could consistently export over 70% of their production.[28]

The small size of the market placed another burden upon Japanese manufacturers. Once they had provided themselves with well equipped factories, and had gained access to the second level sub-market, they were faced with the problem of the capacity utilisation of those factories. The second level sub-market was smaller than the third level sub-market within which they had previously operated, and they also had to compete with advanced foreign manufacturers. Moreover, demand was subject to violent fluctuations in accordance with the business cycle. While it is true that the government sector had as a priority the award of valuable orders to the five big makers, these orders, particularly those from the arsenals, also fluctuated considerably depending on whether the country was at peace or at war. Low capacity utilisation during periods of stagnation put a major burden on them. For example, Niigata's Tokyo machine tool factory, destroyed in the 1923 earthquake, was rebuilt in 1924 with improved equipment, but while the new factory was designed for annual production of Y1.5m. worth of machine tools, average annual production 1925-8 was only valued at just over Y100,000.[29] In order to raise the level of capacity utilisation companies had to have other major products suitable for compensating for fluctuations in machine tool production. Ikegai, for instance, continued to manufacture hot bulb engines, marine diesel engines and high speed rotating printers. Ōkuma manufactured not just machine tools, but various kinds of textile machinery. Niigata produced such items as hot bulb engines, diesel engines and rolling stock.

Research by Hirota Yoshito on the engineering characteristics of these subsidiary products of machine tool builders has noted the five following points. Firstly, the required precision of machining and assembly for these products was almost the same as that required for machine tools. Secondly, product size was nearly the same. The third characteristic was that the size of production lot was similar. Clearly, these three are all conditions for using the same production equipment for both purposes. The fourth point was that the weight of castings, in the sense of both significance and actual weight, was considerably higher in the subsidiary products. Since the actual weight of cast components occupies a large percentage in the weight of a machine tool, castings have a substantial weight and significance in machine tool production, forcing producers to have a foundry with a relatively large capacity. While the large capacity could often become a burden to the producer, since it might lie idle if machine tools sales stagnated, if a producer could find adequate subsidiary products in which castings had a substantial weight it could also be an advantage. Production of subsidiary products could enable a producer to utilize and invest in the capacity of the foundry, and sustain research and development into casting technology. Finally, Hirota found that the engineering knowhow required for the design of these products was not that different from that required for machine tools, a condition reflecting the need for economising on engineering resources.[30]

Hirota's observations provide the key for understanding the significance of these subsidiary products. They enabled machine tool builders to make optimum use of their expensive equipment and their limited engineering resources, helping them to survive the fluctuating demand in the small domestic machine tool market offered by a late industrialising country.

The Role of Oil and Gas Engines

Among these subsidiary products, it is the oil-fired engine which merits particular note. Ikegai and Niigata depended on the hot bulb engine, a semi-diesel engine using a hot bulb as a supplementary device for ignition, as a key subsidiary product in the early stages of their development. At a more advanced stage, they adopted the marine diesel engine as the major subsidiary product. The customers for these engines were fishermen. In fact, small oil and gas engines for small concerns were typically a springboard for a technical quantum leap not only for machine tool builders, but for many other engineering firms as well. This can be confirmed by looking at Table 2. The item with the largest number of firms in the table is 'small ships and repairs' (101), followed by 'oil and gas engines' (92). While there are no examples of conspicuous upgrading among the small shipbuilders at the time, we find numerous examples of engine manufacturers which subsequently developed into well-established engineering firms. Tobata Castings, for example, which began to copy the production of kerosene-fired marine engines around this time, entered into the manufacture of automobiles in the 1920s, becoming Nissan the following decade. Another car manufacturer, Daihatsu, also started by manufacturing gas engines. Yanmar, the famous diesel engine manufacturer, started by installing, maintaining and repairing gas-fired engines, progressing to the manufacture of oil-fired engines in the 1910s. Their customers, too, were small firms, farmers and fishermen.

As has been shown in the case of Ikegai, small Japanese firms in the mid-Meiji period possessed no prime mover. The machines were driven by human power. Although small firms did desire the introduction of a prime mover, the steam engine was not suitable for small firms, as the Western experience showed. The result was that it was not until towards the end of the Meiji period that small Japanese firms found an adequate prime mover, in the form of gas-fired engines. However, it was just around this time that electricity supplies were developing, and small entrepreneurs found in the electric motor the ideal prime mover. The prevalence of gas-fired engines in Japan was thus very short-lived. Even so, they still played a memorable role in the technical learning process in the Japanese engineering industry. Many engineering firms trained themselves for the manufacture of internal combustion engines by copying the production of imported gas-fired engines. As small entrepreneurs' demand shifted towards electric motors, firms' products shifted towards the manufacture of oil engines for the primary sector (gas engines declined because of the restricted availability of gas). Engines for fishing boats, rice milling equipment, irrigation pumps and other uses constituted an appropriate market for small engineering firms. I will focus here on the production of marine engines for fishing boats.

It was in 1903 that the marine petrol-fired engine for small boats was first imported to Japan, such engines being used to drive the ferries transporting passengers to the Fifth National Exhibition for the Promotion of Industry. After the exhibition such marine engines diffused rapidly, first to other ferries, and then to fishing boats.[31] Along with this diffusion, small engineering firms took to producing copies of imported engines. These engines were traded on the market using the name of the company which had produced the original model. For instance, a Union-type engine meant a kerosene-powered engine copied from a marine engine imported from the American Union Gas Engine Company. It was, in fact, this engine which was the most widely copied and diffused engine in the early stages of development. Another important type was the Bolinder-type engine, a hot bulb engine copied from the original model produced by Bolinder Meks. Verkstadt A.B., a Swedish firm. This engine diffused rapidly into the fishing boat market, replacing Union-type engines, as its fuel cost was about half that of a kerosene engine. The hot bulb engines manufactured for the first time by Ikegai and Niigata were of a more primitive type than the Bolinder engine.

The introduction of powered fishing boats was a huge innovation in the fishing industry. Makino Fumio estimates that the Japanese fishing industry grew at an annual rate of 3.8% from 1907 to 1939, a remarkably high rate of growth for a primary industry. Analysing the contribution of various factors, Makino concluded that the residual, which roughly represented the effect of technical change, was some 1.5%, most of which he assumed to represent the introduction of powered fishing boats.[32] Without power boats fishing was restricted to inshore fishing grounds, but a hundred miles from the shore everywhere was a rich fishing ground, to which the new powered boats provided access.

The rapid development of the fishing industry was accompanied by a change in the market for engines, as shown in Table 6. As capital was accumulated, rich fishermen began to demand larger boats powered by diesel engines. Union-type engines were improved, modified and developed into a four cylinder kerosene-powered engine with an electrical ignition system. This engine was easy to handle, and was widespread among small fishing boats. The Bolinder-type hot bulb engine was also improved, finding its niche market among middle sized fishing boats. This market structure to a certain degree influenced the course of the learning process of each firm. Tobata established a basis as a manufacturer of four cylinder kerosene-powered engines, shifting later to petrol engines and automobiles. Ikegai and Niigata started with hot bulb engines, and then shifted to diesel engines within the same fishing boat market. Their shift paralleled a technical learning process towards larger sized machine tools. A detailed study of such interactions between market conditions and the learning process, and the resultant trajectories of technical upgrading, will constitute a fertile field for future study.

Some Theoretical Implications

The difficulties of establishing an efficient capital goods sector in a less developed economy have been discussed by many economists. One such example is the work of Nathan Rosenberg.[33] Rosenberg's interesting concept of 'the economy of specialisation' asserts that economies of scale are not important in the capital goods sector, where production made to order is dominant, and so the economy of specialisation becomes important, since the high degree of specialisation required is the key to more efficient learning and technical accumulation. Rosenberg explains the difficulties faced by the capital goods sector in less developed countries along the following lines. His view is that a high degree of specialisation among capital goods manufacturers requires a substantial size of capital goods market. Consequently the small size of the capital goods market in a less developed economy will result in a low degree of manufacturer specialisation and hence in an inefficient capital goods sector incapable of producing anything but expensive, low quality capital goods. The result is stagnation of the economy on the one hand, and on the other a reluctance on the part of local manufacturers to buy local capital goods. This produces a vicious circle, whereby the size of the local capital goods market continues to remain small.

Rosenberg's emphasis on the size of the capital goods market is important. We have seen how the capital goods market played a crucial role in the development of the Japanese machine tool industry. The concept of the economy of specialisation is, however, also important.

While such considerations are outside the scope of the present paper, there is no doubt that this factor played an important role in the subsequent steps of Japanese development. Nevertheless, there is a defect in Rosenberg's argument, in that he presupposes the existence of a uniform and homogeneous market, in which cheap, high quality goods made in the efficient capital goods sectors of the advanced countries enjoy a clear supremacy over expensive, low quality goods produced in the inefficient capital goods sector of the less developed country. Such a picture does not really reflect the reality of the capital goods market in developing countries. The reality is, in fact, that at the top the market is monopolised by expensive, high quality foreign goods, while at the bottom end of the market it is cheap, low quality local goods which have the monopoly. In between there is the possibility of a small market within which both foreign and local products will compete. The three cases of Japan, Taiwan and Hong Kong examined in this paper demonstrate that it is possible to find various alternative patterns of technological upgrading, starting from the bottom end of the market, which is intrinsically favourable to the late-comer's own capital goods sector.

This proposition, namely that a manufacturer needs to start with an innovative product at the bottom end of the market, will recall for some readers the concept of appropriate technology. In fact, our understanding of the starting point may well be close to that of appropriate technology, and to the neo-classical concept of comparative advantage. However, our analysis of the process as a whole is more likely to point to the limitations of any static understanding of comparative advantage or appropriate technology. If the product is appropriate to local conditions (or factor endowment), it will induce innovation and direct the resulting development of the industry in the case of specific customers. However, such development will soon destroy the basis for the appropriateness of the product. The Japanese experience suggests that the short-lived nature of a product is intrinsic to appropriate technology (or comparative advantage). Appropriateness itself is determined by the nature of the bottom end of the market, which reflects the conditions in the less developed economy. While development rapidly changes these conditions, it also means that the limits of the small, lowest level market are very quickly reached. The economic potential of appropriate technology has by then been exhausted, and a quantum leap to the higher level market is required. This is why a developing country needs to make continuous efforts at technological leaps if it is to sustain a process of economic growth.

Our considerations on the barriers to such a leap have stressed the importance of capital accumulation, which in turn suggests the possibility of following a capital-intensive path in establishing a capital goods sector in a less developed country. In fact, in Japan large companies in the shipbuilding industry constituted the parent organizations of various capital goods manufacturers. As exemplified in the case of Niigata, for example, a first class capital goods manufacturer could often originate from the well-equipped machine shop of a large mining company. However, it is not necessary here to raise the question of whether the course followed should be capital-intensive or labour-intensive. The important question is how the barriers may be overcome.

It is in the context of this question of overcoming the barrier that Fransman suggested the need for government help in making successful technical leaps.[34] Indeed, it is possible to find a range of cases in which a successful leap took advantage of help given by government or public institutions in order to overcome the barriers to such leaps. On the other hand, though, there are also many cases where excessive protection has damaged entrepreneurs, discouraging them from challenges and the spirit of risk-taking, and from seriously responding to the problem of capacity utilisation. My own feeling is that a certain degree of help can be effective in as far as it does not hinder market competition, but the question of how far such help should be given must await further investigation.

Endnotes

1. Alice H.Amsden, 'The Division of Labour is Limited by the Type of Market: the Case of the Taiwanese Machine Tool Industry', World Development 5, 3, 1977, pp.217-233; Alice Amsden, 'A Technological Perspective on the General Machinery Industry in the Republic of Korea', in M.Fransman (ed.), Machinery and Economic Development (London, Macmillan, 1985); Martin Fransman, 'Learning and the Capital Good Sector under Free Trade: the Case of Hong Kong', World Development 10, 11, 1982, pp.991-1014; M.Fransman, 'International Competitiveness, Technical Change and the State: the Machine Tool Industry in Taiwan and Japan', World Development 14, 12, 1986, pp.1375-1396; M.Fransman, The Market and Beyond: Cooperation and Competition in Information Technology Development in the Japanese System (Cambridge, Cambridge University Press, 1990).

2. Yamada, Moritarō, Nihon Shihonshugi Bunseki (Analysis of Japanese Capitalism) (Tokyo, Iwanami Shoten, 1934) is a classic example of such works. Yamada characterised the upper part of the dual structure as key industries closely linked to the military establishment, and the lower part as family-operated cottage industries based on putting-out systems and semi-slave wage labour.

3. Nakaoka, Tetsurō, et.al., Kindai Nihon no Gijutsu to Gijutsu Seisaku (Technology and Technology Policies in Modern Japan) (Tokyo, Tokyo Daigaku Shuppankai, 1986).

4. Morozumi, Munekazu, Imono Kōgyō no Hatten to Sangyō Kinenbutsu (The Development of the Casting Industry and its Monuments), in Nihon Kagaku Gijutsu Shinkō Zaidan (ed.), Sangyō Gijutsu no Rekishiteki Tenkai Chōsa Kenkyū (Study of the Historical Development of Industrial Technology) (Tokyo, 1982), p.46.

5. Ueyama, Kazuo, Kikai Seishi no Kakuritsu to Sanshi Gijutsu (The Establishment of Machine Reeling for Silk, and its Related Technology), in Unno, Fukuju (ed.), Gijutsu no Shakaishi (Social History of Technology) (Tokyo, Yuhikaku, 1982), vol.3, pp.190-1. Suzuki, Jun, Kikaiseishi-yō Kikan Seizō no Tenkai (Boiler Making for the Cocoon Reeling Industry: Nagano Prefecture in the Early and Mid-Meiji Era), Shigaku Zasshi 101, 7, 1992, pp.1267-1295.

6. In the manufacture of products like narrow-width looms, small ships, steam boilers and noodle manufacturing machines, an important role could be played by workers such as traditional loom or ship carpenters, casting craftsmen and sheet copper workers. Traditional skills were also useful in the manufacture of parts such as gears, so long as these could be cast. However, for the manufacture of steam engines, gas and oil-fired engines, machine tools and other similar products, modern engineering techniques were required. It was here that the activities of workers formerly employed by arsenals, railway factories and a few private engineering firms were crucial.

7. Alice H. Amsden, 'The Division of Labour is Limited by the Type of Market', p.220.

8. Martin Fransman, 'Learning and the Capital Goods Sector Under Free Trade', p.1003.

9. Ibid., p.1004.

10. A brief history of the Japanese cotton spinning and weaving sectors in the late nineteenth century is in Tetsurō Nakaoka, 'The Transfer of Cotton Manufacturing Technology from Britain to Japan' in D.J.Jeremy (ed.), International Technology Transfer: Europe, Japan and the USA, 1700-1914 (London, Edward Elgar, 1991), pp.181-198.

11. The description here is largely based on Ishii, Tadashi, 'Sen'i Kikai Gijutsu no Hatten Katei' (The Development of Textile Machinery

Engineering) in Nakaoka et.al., op. cit., pp.107-161.

12. The case of Sennan (southern Osaka) region is discussed in Takeshi Abe & Osamu Saitō, 'From Putting-Out to the Factory: a Cotton Weaving District in late Meiji Japan', Textile History 19, 2, pp.143-157.

13. Ishii, Tadashi, op.cit., p.124.

14. Ibid., p.126.

15. Toyoda Jidō Shokki 40-nen Shi (Forty Years of Toyoda Automatic Loom Works) Kariya, Toyoda Jidō Shokki (1967) pp.91-2.

16. Ishii, Tadashi, op.cit., pp.109, 114-5.

17. A.H.Amsden, op.cit., p.220.

18. Hirota, Yoshito, Nippon to Taiwan ni miru Hattentojōki no Kōsakukikai Kōgyō (The Machine Tool Industry in the Making: the Cases of Japan and Taiwan), in Nakaoka, Tetsurō (ed.), Gijutsu Keisei no Kokusai Hikaku (International Comparison of Technology Formation) (Tokyo, Chikuma Shobō, 1990), pp.140-175.

19. Sawai, Minoru, 'Kōsaku Kikai Kōgyō no Jūsōteki Tenkai: 1920-nendai o Megutte' (The Hierarchical Development of the Machine Tool Industry, with Special Reference to the 1920s), in Minami, R. & Kiyokawa, Y. (eds.), Nihon no Kōgyōka to Gijutsu Hatten (The Industrialization of Japan and the Development of Technology) (Tokyo, Tōyō Keizai Shinpōsha, 1987), pp.174-193.

20. A.H.Amsden, op.cit., p.223.

21. Kuramae Kōgyōkai, Kikai Kōgyō Chōsasho (Report on the Machinery Industry) (Tokyo, Kurame Kōgyōkai) (1927).

22. Sawai, Minoru, 'Kikai Kōgyō' (Machinery Industry), in Nishikawa, S. & Abe, T. (eds.), Nihon Keizaishi (Economic History of Japan), vol.4, Sangyōka no Jidai (Age of Industrialization) (Tokyo, Iwanami Shoten, 1990), pp.244-6.

23. 'Gaijin Gishi o kakomu Seisan Gijutsu Zadankai' (A Talk with a Foreign Engineer on Production Engineering), Nihon Nōritsu, 1, 7, 1942, p.14.

24. Sawai, Minoru, 'Kōsaku Kikai Kōgyō', p.178.

25. Daniel Chudnovsky, Masafumi Nagao & Staffan Jacobsson, Capital Goods Production in the Third World (London, Frances Pinter, 1983), p.51.

26. The description of Ikegai is based on Ikegai Tekkōsho, Ikegai Tekkōsho 50-nen Shi (Tokyo, Ikegai Tekkosho, 1941).

27. Hirota, Yoshito, op.cit., pp.141-51.

28. Ibid., pp.162-3.

29. Sawai, Minoru, 'Kōsaku Kikai Kōgyō', p.183.

30. Hirota, Yoshito, op.cit., p.165.

31. Uchimaru, Saiichirō, Nainen Kikan (Internal Combustion Engines), vol.2 (Tokyo, Maruzen, 1931), pp.542-8.

32. Makino, Fumio, 'Nippon Gyogyō ni okeru Gijutsu Shinpō' (Technological Changes in Japanese Fishing), in *Gijutsu to Bunmei* 5, 1 (1989), pp.47-64.

33. Nathan Rosenberg, 'Capital Goods, Technology and Economic Growth' in Rosenberg, *Perspectives on Technology* (Cambridge, Cambridge University Press, 1976), pp.141-50.

34. M.Fransman, 'The State and Technical Change' in M.Fransman, *Technology and Economic Development* (Brighton, Harvester Wheatsheaf, 1985), pp.95-107.

Table 1: Japanese machinery sector in 1911

Firm Size (by number of workers)	Prime Mover & Parts	Textile machinery	Agricultural & Mining machinery	Electrial machinery	General machinery	Ship	Rolling Stock	Cart bicycle & Others	Total
5 - 9	67	70	27	14	176	50	4	92	500
10 - 29	76	36	26	11	96	32	6	12	295
30 - 49	23	6	6	6	10	8	1	1	61
50 - 99	11	2	4	3	13	9	5	2	49
100 - 199	1	4	3	1	2	1	4	1	17
200 - 499	4		1	3	1	7	5		21
500 - 999				1		3			4
1000 - 1999						3			3
2000 - 4999						1			1
5000-						1			1
Total	182	118	67	39	298	115	25	108	952

Source: Meiji 44-nen Kōjō Tsūran (List of Factories in 1911)

Table 2: Classified list of products by small firms and number of firms producing them.

Prime mover and related machinery:	205	Oil and gas engines	92
		Steam boilers	59
		Steam engines	48
		Electric motors and generators	6
Transport equipment:	213	Small ships and repair	101
		Various carts	75
		Bicycles and repair	37
Machinery related to urban lives:	153	Pumps	47
		Metal products for building	18
		Printing and related machinery	26
		Electricity, gas and water supply related	32
		Food processing machinery	30
Machinery invented locally:	108	Narrow looms and others	48
		Rickshaws	13
		Noodle manufacturing machines	7
		Rice milling equipment	45
Machinery for the primary sector:	56	Mining machinery	22
		Sawmill machinery	10
		Cotton beating machines	11
		Agricultural machinery	13
Textile machinery:	55	Machinery related to cotton spinning	22
		Devices for silk reeling	14
		Devices for weaving	8
		Sewing machine and repair	7
		Machinery related to dyeing	4
Machinery for export-oriented labour-intensive industries (match, knitwear, braid, etc.):	15		
Machine-tool:	18		
Various machines:	130		
Repair to machines:	61		
Machinery parts:	26		

Source: Meiji 44-nen Kōjō Tsūran.

Table 3: Distribution of textile machinery firms (1911)

Number of firms

Firm size (by number of workers)	Spinning	Silk reeling	Weaving	Knitting	Sewing	Others
5 - 9	10	8	26	2	7	17
10 - 29	13	1	18	1		3
30 - 49	1		2	1		2
50 - 99			2			
100 - 199	2		2			
Total	26	9	50	4	7	22

Table 4: Sales of power looms developed by Sakichi Toyoda in the early period of the Toyoda Loom Works.

Classification	Type	Year developed	Construction	Total number of looms sold
Narrow width	38-nen (1905)	1905	Wood	947
	39-nen (1906)	1906	Wood	2,307
	Simplified	1906	Wood	4,021
	A	1907	Wood-iron	1,846
	B	1907	Wood-iron	4,731
	K	1908	Iron	213
	I	1909	Wood-iron	6,088
	L	1909	Iron	15,247
	Total			35,400
Broad width	G	1907	Wood-iron	180
	H	1908	Iron	3,742
	Total			3,922

Source: Toyoda Jidōshokki 40nen-shi, p.53.

Table 5: Distribution of machine-tool builders by size

Firm size (by number of workers)	1929	1936
5 - 9	332	347
10 - 29	100	284
30 - 49	20	67
50 - 99	6	53
100 - 199	3	11
200 - 499	4	5
500 - 999		4

Source: Shoko-sho (Ministry of Industry and Commerce) ed., Kojo Tokeihyo (Statistics on Factories).

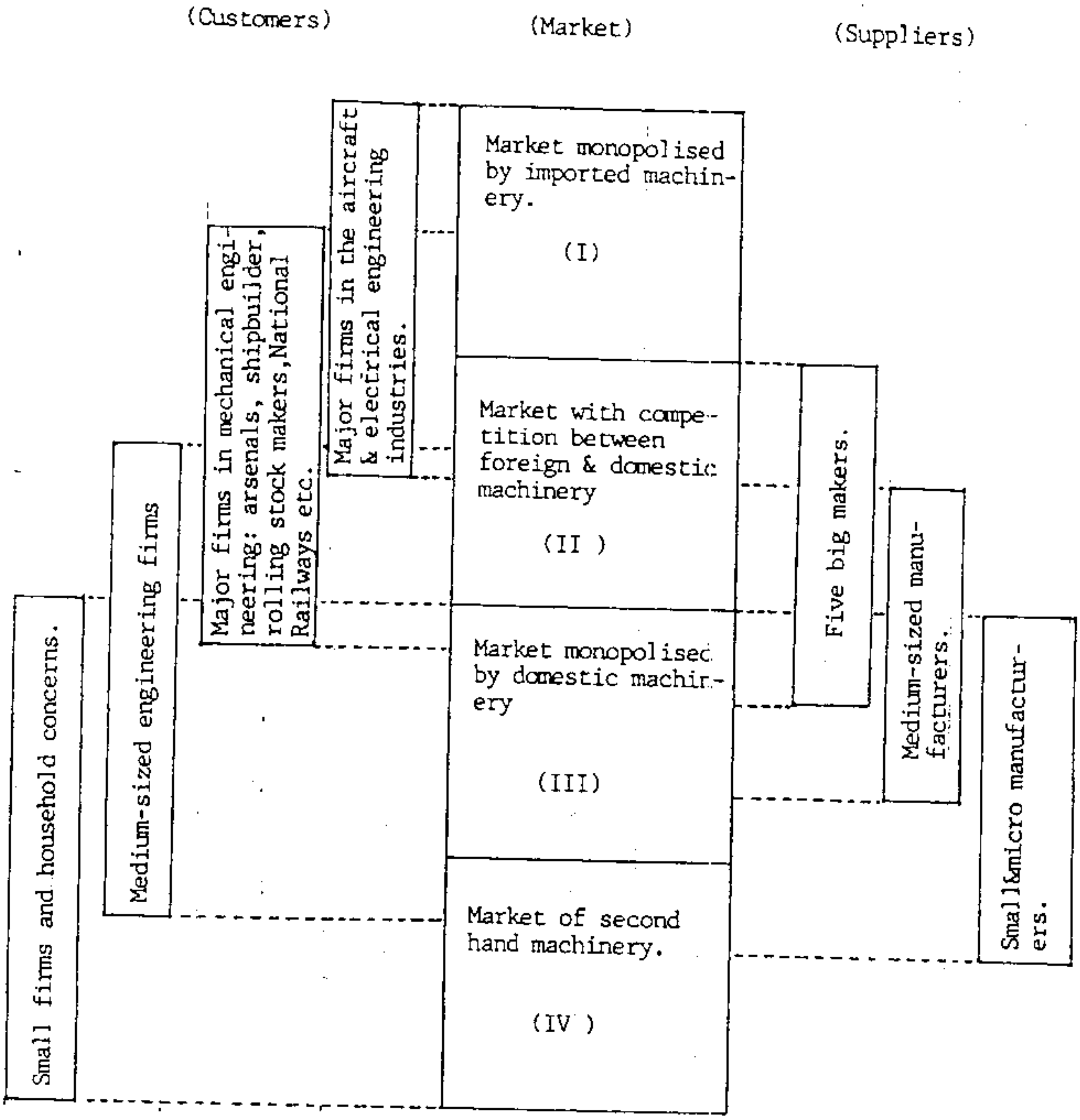
Table 6: Number of fishing boats classified by their engines.

	Diesel engine	Hot bulb engine	Four cycle kerosene engine	Total
1924	49 (32)	9,031	260	9,340
1929	221 (163)	15,389	9,482	25,093
1934	657 (288)	20,890	25,121	46,668
1939	655 (549)	28,364	46,194	75,213

* The figures in brackets show the number of boats with diesel engines of more than 100Hp.

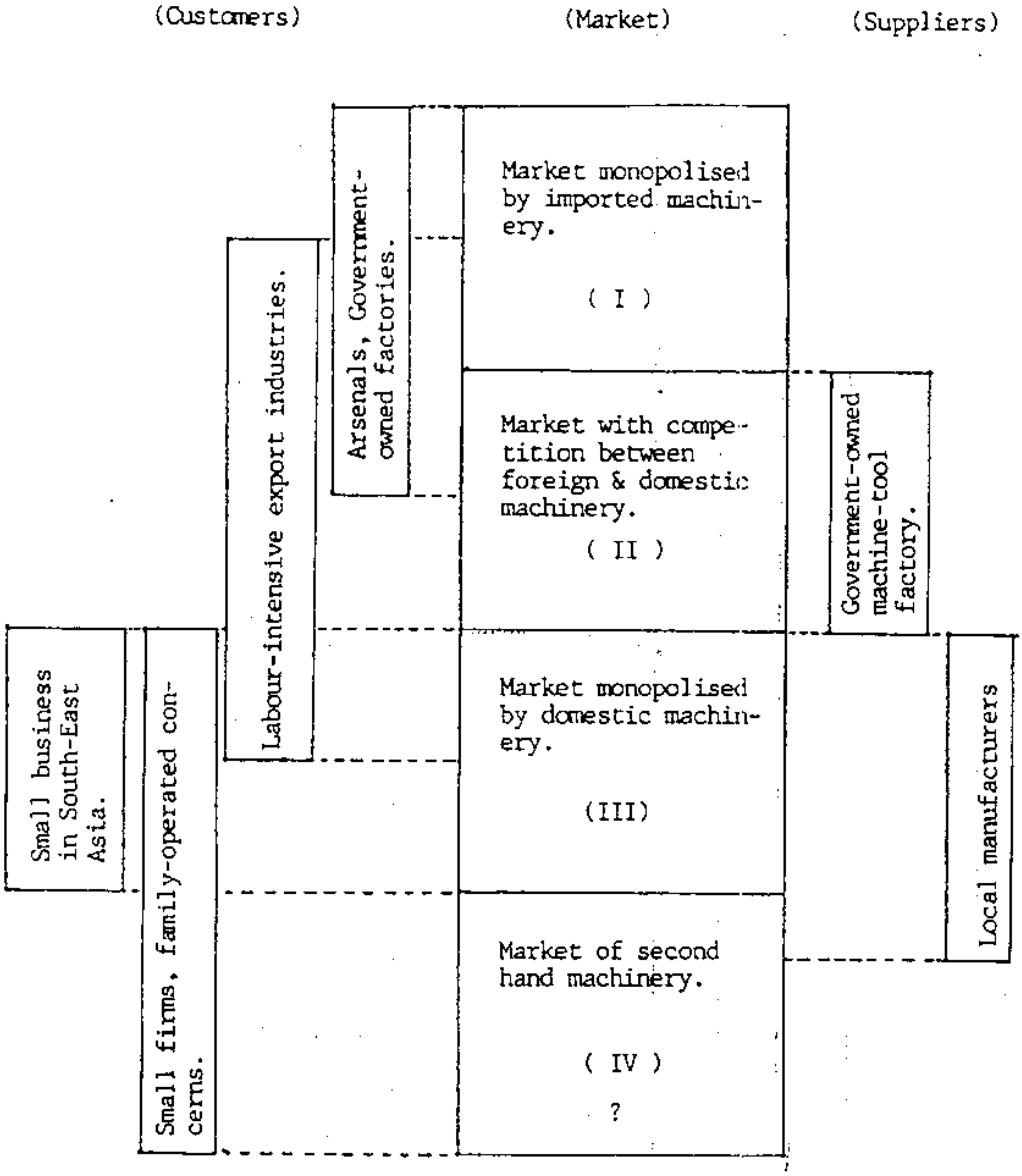
Source: F. Makino 'Technological Changes in the Japanese Fisheries' Gijutsu to Bunmei, Vol.5 (1989) No.1, p.51.

Fig.1: The structure of the Japanese machine-tool market in the 1920s.



Source: R.Minami & Y.Kiyokawa eds. Nippon no Kōgyōka to Kijutsuhatten (The Industrialization of Japan and the Development of Technology) , 1987, p.278.

Fig.2: The structure of the Taiwanese machine-tool market in the 1960s.



Note: Though Dr. Amsden didnot refer to the second hand market, the auther assumes the existence of the fourth submarket in Taiwan too.